SHRIMP CULTURE IN THE UNITED STATES[1]

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ABSTRACT

Early attempts to rear shrimp commercially in the United States were patterned after successful methods in use in the Orient. Economic, legal and social restrictions in the United States contributed to the failure of these methods. A review of recent research results is presented and typical commercial ventures of several types are examined.

INTRODUCTION

Shrimp culture activities in the United States have been characterised by three phases of development. I've assigned labels to these phases as follows:

1. Chickens in the woods
2. What's a shrimp?
3. Cats and rats.

I believe the reasons for these headings will be obvious.

CHICKENS IN THE WOODS

In the early 1960s, about the time of the price increases mentioned earlier, people suddenly became aware of shrimp culture in South-east Asia, and began thinking about shrimp farming in the United States. By the late 1960s larval culture techniques were available making the prospect of raising shrimp commercially even more attractive.

Now I want to draw a parallel with raising chickens. Any of you who have raised chickens realise that hatching and rearing chicks is not all there is to the chicken business. If you raise chicks then release them in the wild and plan to come back in 4 months for the harvest you'll have problems. Although you may harvest a few, most will have died.

This procedure which sounds foolish with chickens is about what people were planning to do with shrimp. The prospective shrimp farmers released postlarvae into natural ponds and came back 6 months later with the hope that by some magical process the ponds would be full of shrimp. Nothing magical occurred. They had the same kind of problems you might expect to have with chickens in the woods. The shrimp did disappear, but that wasn't the kind of magic the shrimp farmers had hoped for. Strangely enough, some people are still thinking along these lines today.

WHAT'S A SHRIMP?

Following the early failures shrimp culturists began to ask questions about shrimp—their habits, foods, requirements, and enemies, and realised we didn't have answers to many of the basic questions. In the late 1960s the research effort in the United States began in earnest. I would like to review the research accomplishments in the United States briefly with emphasis on developments during the last couple of years.

In the area of larval culture there are few new developments. The storage of algal foods by freezing has been useful in eliminating dependence on the timing of the algal cultures. The cells are separated from their culture media by simple centrifugation; concentrated cells are frozen in sea water and later thawed in distilled water.

After testing numerous food organisms we found that a combination of *Skeletonema* sp. and *Tetraselmis* sp. is most suitable. These two species not only provide the necessary nutritional requirements of the larval shrimp, but are relatively easy to culture, to concentrate and to store frozen.

We have long been dependent upon *Artemia* for food during the mysis and early postlarval stages. The possibility that a substitute for *Artemia* may be found has been improved by the availability of micro-encapsulated foods. Feeds coated with gelatin in particle sizes down to 50 microns are now available. Although we don't yet know what to put in these capsules,

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preliminary tests are underway with larval and postlarval shrimp.

Some nutritional problems have been solved but many remain. A suitable form for shrimp feeds is the small worm-shaped pellets produced by an extrusion process. The attractant in a shrimp feed is extremely important because the animals may stop eating a given diet after a few weeks if the attractant is unsatisfactory. Fish solubles, a by-product of the fish meal industry, is a suitable attractant. Considerable effort has also been spent in search of a binder which will hold food intact for long periods in the water and still be suitable from the nutritional viewpoint. An alginate binder is the best we have tested. The nature of the alginate binder requires that the feed be extruded in a wet state and dried following extrusion, an extra step in the manufacturing process which feed manufacturers dislike.

Until recently we have not had a control diet to use as a basis for nutritional comparisons. We do now have a standard diet (Zein-Eldin and Meyers, in press) which is fairly good from the nutritional standpoint, contains inexpensive ingredients (Table 1), and can be manufactured on a small scale.

It is becoming obvious that the environmental changes, which are normal during the life cycle of shrimp, must be duplicated, to varying degrees, to produce conditions for optimum growth of the shrimp. We must begin thinking beyond the tolerances of the animals and simple survival to optimum conditions for growth. Many details of the effects of metabolic wastes, light, and sea water chemistry must be examined as well as aspects of the shrimp's behaviour such as burrowing. At present very little data of this type are available.

Unfortunately, very little new work has been done in the area of pond culture methods. Most of the methods used in the United States have been used for some time in Asia. I found it very difficult to summarise the results obtained by the four main research groups working with pond culture of shrimp (University of Miami, State of Texas, State of Louisiana and Texas A&M University). Because of the different approaches, the different stocking densities and the different environmental conditions, research results frequently cannot be compared. Two general relationships could be reçognised, however: a relationship between stocking density and size at harvest, and a relationship between stocking density and yield. If experiments of 90-120 days duration in static ponds are considered, the relationships can be approximated as follows:

1. Size at harvest ranges from about 120 mm in total length for densities below 20,000 per hectare to about 80 mm for densities over 250,000 per hectare.
2. Yield ranges from 100-200 kg/ha (heads-on) at stocking densities of 20,000-40,000 per hectare to 400-600 kg/ha at densities of 250,000-300,000 per hectare.

The problem of sexual maturation of females in captivity is receiving considerable attention from researchers. In addition to the reported successes in maturing female shrimp in Japan (for which little factual information

Table 1. Composition of standard diet in use at the Galveston Laboratory[a]

Component	Percentage	Source
Shrimp meal, sun-dried	31.5	Blum and Bergeron, Houma, Louisiana
Fish meal (menhaden)	8.0	
Soybean meal ('Promine-D')	3.0	Central Soya Company, Chicago, Illinois
Rice bran ('Protex-29')	49.0	Riviana Foods, Inc., Houston, Texas
Vitamin diet fortification mixture	2.0	Nutritional Biochemicals, Cleveland, Ohio
Fish solubles	2.0	
Lecithin ('Alolec')	1.0	American Lecithin Company, Long Island, New York
Kelgin (High velocity algin)	2.5	Kelco Company, San Diego, California
Sodium hexametaphosphate ('Calgon')	1.0	

[a] From Zein-Eldin and Meyers (In press).

is available), at least two research teams have induced maturation and spawning of captive, wild penaeid shrimp. A research team in Puerto Peñasco, Mexico composed of biologists from the University of Arizona and the University of Sonora, and a team of French scientists at the CNEXO facility in Tahiti have both accomplished maturation under similar conditions. Both groups were using a continuous exchange of high quality, oceanic water through their tanks and both had reduced light intensity by shading the tanks. The species matured successfully to date have been *Penaeus californiensis* (Mexico), *P. semisulcatus*, *P. merguensis* and *Metapenaeus monoceros* (all in Tahiti).

We have not yet matured species from the Gulf of Mexico even though environmental factors such as low light intensity and good water quality have been conducive to partial development of the ovaries. Eyestalk ablation can be used to induce vitellogenesis; however, normal spawning does not follow completion of vitellogenesis in ablated animals.

The final topic I want to mention in this section is intensive culture and the applications of engineering methods to high density culture. I am predicting this will be the most active area of development during the next few years even though efforts along these lines are just now beginning. The Japanese have not been interested in high-density culture until recently because more traditional methods were profitable in Japan.

The need for intensive culture arises with animals that require animal foods for part or all of their diet. Carnivores can graze on natural animal foods just as herbivores do; however, the density of carnivores which can be supported on natural foods is not nearly as attractive economically as is the density of herbivores. Therefore, we need to boost production per unit of area, and we do this by adding feeds and controlling the environment.

At the Galveston Laboratory we are just beginning to work in a closed system in a greenhouse which permits year-round production. By aerating the water heavily, encouraging algal growth and insuring adequate circulation of the water we have had surprisingly good results.

CATS AND RATS

The third phase of shrimp culture activity actually hasn't followed the second phase because the second is not complete. I might also label this phase the phase of 'Grand Plans'.

For illustration I want to tell you about my cat farm. I'm going to buy an old building in Galveston for $1,000. This building is going to be my cat farm where I will raise cats for their fur. Cat pelts are worth only about 40c each so I'll need lots of cats, in fact about 20,000 of them. Now if you know anything about cats you know that if you start with a few hundred you will soon have 20,000. The cats will be fed rats, and if you know anything about Galveston you know that won't be a problem. Rats need to eat too, of course, so I will feed the cat carcasses to the rats.

Since a cat is ready to pelt at 20 weeks of age, I will pelt 1,000 cats per week. The income will be $400 per week minus $100 which I will pay the cat skinner. This leaves a net income of $300 per week from my $1,000 investment.

I'm sure you've all talked with entrepreneurs who have similar plans for shrimp farming. Typically the plans include a scheme for selling shares in the company, and frequently the budding businessman has ignored advice from biologists.

Fortunately not all the 'Grand Plans' are this bad. In fact, some of the commercial trials have been very good efforts from which a great deal can be learned. I want to review several representative commercial efforts which I feel were good efforts, looking both at their successes and their shortcomings. These commercial firms (which will not be identified by name) worked in the following environments:

- Company A—Natural marsh area
- Company B—Natural bay plus ponds
- Company C—Ponds
- Company D—Outdoor raceways using waste heat.

Company A began using natural marsh areas in southern Louisiana which have little value except for wildlife and oil. The soils in this area are very loose with a high organic content. During oil drilling and exploration the oil companies dug many canals through the area. This company planned to use these waterways plus natural and artificial ponds to rear shrimp that entered the waters naturally as postlarvae. Considerable experimentation was conducted with levee construction, feeding methods, methods of harvesting and methods for control of predators.

Even though the natural environment supported shrimp, the biologists found the environment to be very unstable. Disturbances such as dike construction caused many problems. The dikes sloughed continuously and disturbances of the high organic soils created high oxygen demands in the ponds. Dike construction and maintenance proved to be prohibitively expensive partly because of damage by burrowing mammals. Harvesting a high proportion of the crop was virtually impossible because the water could not be completely drained from the enclosures. Commercial efforts were abandoned after a few years.

Company B transferred Japanese larval culture technology to the United States. Their larval culture procedures have been consistently successful. The grow-out procedures also were patterned after Japanese methods with the following exceptions:

1. The area of the culture enclosures ranged from a 120-hectare pond to a 1,000-hectare natural bay, while Japanese enclosures are much smaller.
2. A retaining net 5.6 km long was constructed across the mouth of the large bay area.
3. Much less tidal exchange occurs along the Gulf of Mexico than in the Inland Sea of Japan.
4. Predators have not been controlled as successfully as they have in Japan.
5. Only supplemental feeding was used.

Because the biologists have only limited control over these large bodies of water survival has been poor. Harvests have ranged from 75,000 kg to 225,000 kg during the period 1971-1973.

The pilot studies by Company C are typical of several which have taken place in Central America utilising artificial ponds. The company established its operations in Honduras to take advantage of low labour costs, low taxes, low land costs and freedom from regulations such as the pollution laws in effect in the United States. Two problems have hampered culture efforts in Central America. First the labourers, although inexpensive, are not always productive. Second, problems of obtaining equipment and maintenance services on the equipment have caused difficulties. Although reports of growth and survival of shrimp in Company C's ponds were good, this pilot operation was discontinued for undisclosed reasons.

The efforts of Company D represent the most progressive commercial effort in the United States to date. The company hired a competent, experienced staff and constructed a modern hatchery. Raceways were constructed near an electrical power plant to utilise waste heat during the cooler months.

The procedure used in the 0.2 hectare raceways was to stock at very high densities (up to 700,000 per hectare), use a rapid exchange of water, fertilise heavily and feed heavily. Even with the rapid exchange of water growth sometimes stopped at 60 or 70 mm total length, especially at the higher densities. Generally the operation appeared to be quite successful although figures on production and costs are not available.

A major problem associated with this trial was the rocky, porous nature of the soil. It was necessary to use butyl rubber liners in some raceways in order to hold the water. This type of liner is quite expensive ($3.00-$4.50 per m^2). The only indication of the profitability of this operation has been the termination of commercial scale trials in the United States and the development of new facilities in Central America by Company D.

Although much more could be said about the commercial activities in the United States, let me say in summary that there are no outstanding successes yet and probably no profitable operations.